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STRONG INTERACTION PHYSICS IN THE NAL BUBBLE CHAMBER†

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A large bubble chamber will have a set of capabilities which will make it a unique tool for the study of strong interactions at NAL. Although these capabilities have been widely discussed, let us make explicit the most important of them.

1. It is a 4π detector with which one can study a wide variety of interactions and obtain precise and unbiased information on the direction and momentum of charged secondaries. Its ability to provide this information is not dependent on the number of the charged secondaries.

2. It has high spatial resolution and allows clear visibility of the interaction and decay vertices. This means that the decay of short lived charged hyperons will be identifiable as well as lambda and K_s decays which occur within the chamber volume. The high three dimensional spatial resolution of the bubble chamber is worthy of emphasis since all of the existing hyperons (and the known anti-hyperons) have been discovered in bubble chambers and for some (e.g., Ω^-) this is the only instrument with which they have been observed.

3. Bubble density and delta-ray information provide a means of particle identification over a wide range of momenta.

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4. All stopping positive tracks can be positively identified by their characteristic decay products. In particular, range provides a very accurate method of determining the momenta of slow recoil protons if they stop within the chamber volume. This is of particular interest in the study of diffraction disassociation processes which are of great significance at high energies. The ability to observe 'spectator' protons in reactions which occur in deuterium make this a unique instrument for observing reactions which involve the lightly bound neutron of the deuterium nucleus.

5. A portion of the neutral secondaries which are produced will interact within the chamber volume. The possibility of surrounding the liquid hydrogen or deuterium of the central portion of the chamber with a track sensitive liquid hydrogen-neon mixture would greatly enhance the fraction of these secondaries which would be detected. Using this technique, missing neutral particles can be determined with high efficiency at almost a 4π solid angle. This is especially useful at high energies where very probable production of neutrals would prevent analysis in pure hydrogen or deuterium or in smaller chambers. Typical of the interesting ways this neutral detector could be used is the reduction obtained in the number of events that would not have to be measured by using the neutral detector in the neon-hydrogen mixture as an anticoincidence at the scanning level. Furthermore, delta ray analysis in neon allows separation of protons and K-mesons

up to several GeV.

The above qualitative properties are ones which make a large bubble chamber a distinctive and unique instrument for the study of strong interactions. These properties and in particular its high spatial resolution and extraordinary ability to provide us with an immense amount of reliable information about a single event make it an invaluable tool for studying the unexpected. It would be very short sighted to assume that physics at 200 GeV was fully contained in extrapolations from our knowledge at lower energies and hence provide only those tools which were capable of making high statistics measurements of these expected processes.

There is preliminary evidence[1] that the setting error in the Brookhaven National Laboratory 7-foot chamber is smaller than was expected by some people.

If other tracks obtained in routine operation of the 7-foot sustain the quality exhibited by the "early run" track, it appears that the setting error of the NAL 30,000 liter chamber will be only 1-1 1/2 that of the BNL 80" chamber. This implies that the chamber will have considerably greater precision than has been assumed in the NAL summer studies of the last two years. In this light we would like to reinterpret some of the work in these papers. In particular, we would like to point out that the track length of secondaries needed to have optimumly matched errors now becomes much smaller. Carrying on in the framework of the work done by Kraemer and

Derrick[2] in the 1968 NAL Summer Study, we plot in Fig. 1 the optimum track length needed to minimize angle errors versus the momentum of the particle for four values of the setting errir, ε For $\varepsilon = 100\mu$ we require track lengths of only 1.2-3.1 m for momentum 20-100 GeV/c. The contributions to the momentum error come from two sources. One is from the measuring error and this is plotted in Fig. 2 for various momenta again with $\varepsilon = 100\mu$. Also plotted in Fig. 2 is the contribution due to multiple scattering. These give comparable contributions when track lengths are less than 2.7 m for all momenta below 100 GeV/c.

These shorter track lengths required to extract the relevant kinematic data also imply that the majority of the secondaries will not interact in this distance. Table i shows the fraction of events with a given charge multiplicity and given incident momentum which will have all of their secondaries survive to their optimal measuring length. Our model assumes that one secondary is produced with one half the momentum of the primary and the other secondaries share the remainder equally among them. We assume a total cross section of 25 mb. Only in one case do fewer than one half of our events have a track which does not survive to its optimal distance and that is for 8 prongs at an incident momentum of 100 GeV/c.

The above analysis assumes that ones fiducial volume is defined so that one will have available about 2-3 meters of sensitive area downstream of it. Recalling that NAL is currently constructing a 14-foot chamber rather than the one of 25-foot length, we are forced to consider a fiducial volume which begins as close to the beam window as possible. How good an angle and momentum measurement of the beam particle is needed? Work at the NAL summer studies indicated that $\Delta\theta \sim 0.1$ mr and $\frac{\Delta p}{p} \sim 0.1\%$ might be desirable. Clearly this cannot be done by measurements of the beam particles after they enter the chamber, as can be seen from Figs. 2 and 3. We must consider other methods.

Proportional wire chambers[3] have recently been made to operate with wire spacings of 1 mm and it is likely that resolutions of 0.25 mm will be available in a year or two. These chambers have high efficiency ($\sim$100%) and good time resolution ($\sim$25 nsec) and seem ideally suited for use in conjunction with a bubble chamber. Recall that the shortest beam pulse at NAL is about 60 μsec, so that counting the few particles needed for bubble chamber operation presents no problems. A momentum resolution of 0.1% is close to that being designed in the rf separated beam and in itself could not justify these additional detectors. These detectors are essential, however, if the beam angle is to be determined to this precision. One should note that it is useless to attempt to define the beam angle to a precision greater than 0.1 mr (at 100 GeV/c) by this method since the multiple scattering encountered traversing the beam window ($\sim$1/4-inch of steel) is not much less. Finally these proportional chambers could serve one other very useful purpose. If, in addition, a Čerenkov counter were placed in the beam as a mass selector one could tag each beam particle as it enters the chamber not only with its precise angle and momentum but with its mass also.

References

[1] Gerald Myatt, BNL 14349, January 1970.

[2] R. Kraemer and M. Derrick, Parameters of a Large Bubble Chamber, NAL 1968 Summer Study, Volume 1, page 1.

[3] M. Atac and J. Lach, High Spatial Resolution Proportional Chambers. Submitted to Nuclear Instruments and Methods, 1970.

TABLE I.

Fraction of Events in Which all Tracks Survive to Their Optimal Measuring Length

Incident Momentum	Charge Multiplicity			
	2	4	6	8
100 GeV/c	0.67	0.58	0.52	0.48
80	0.70	0.61	0.56	0.52
60	0.73	0.65	0.60	0.57
40	0.78	0.71	0.66	0.63

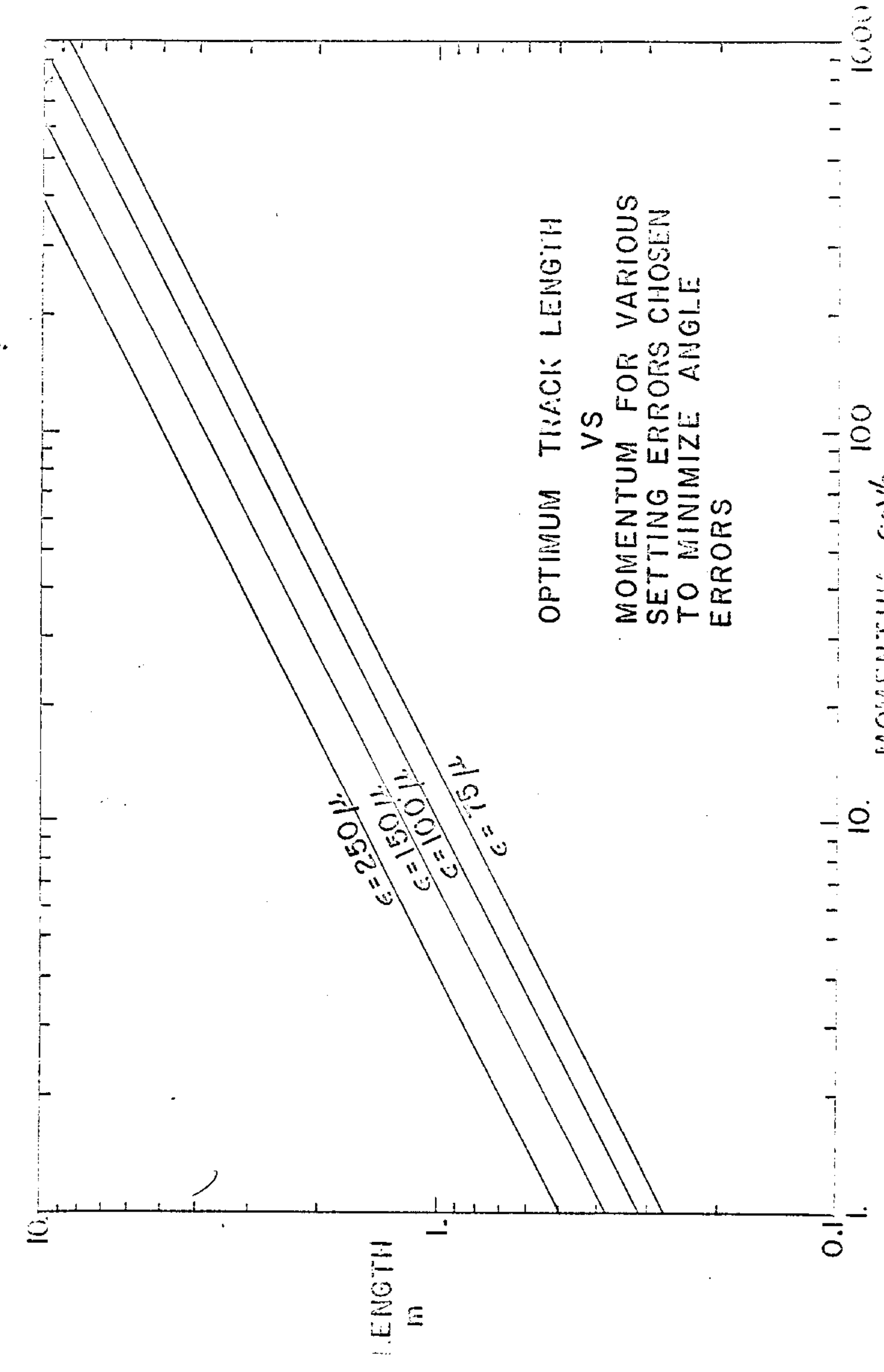
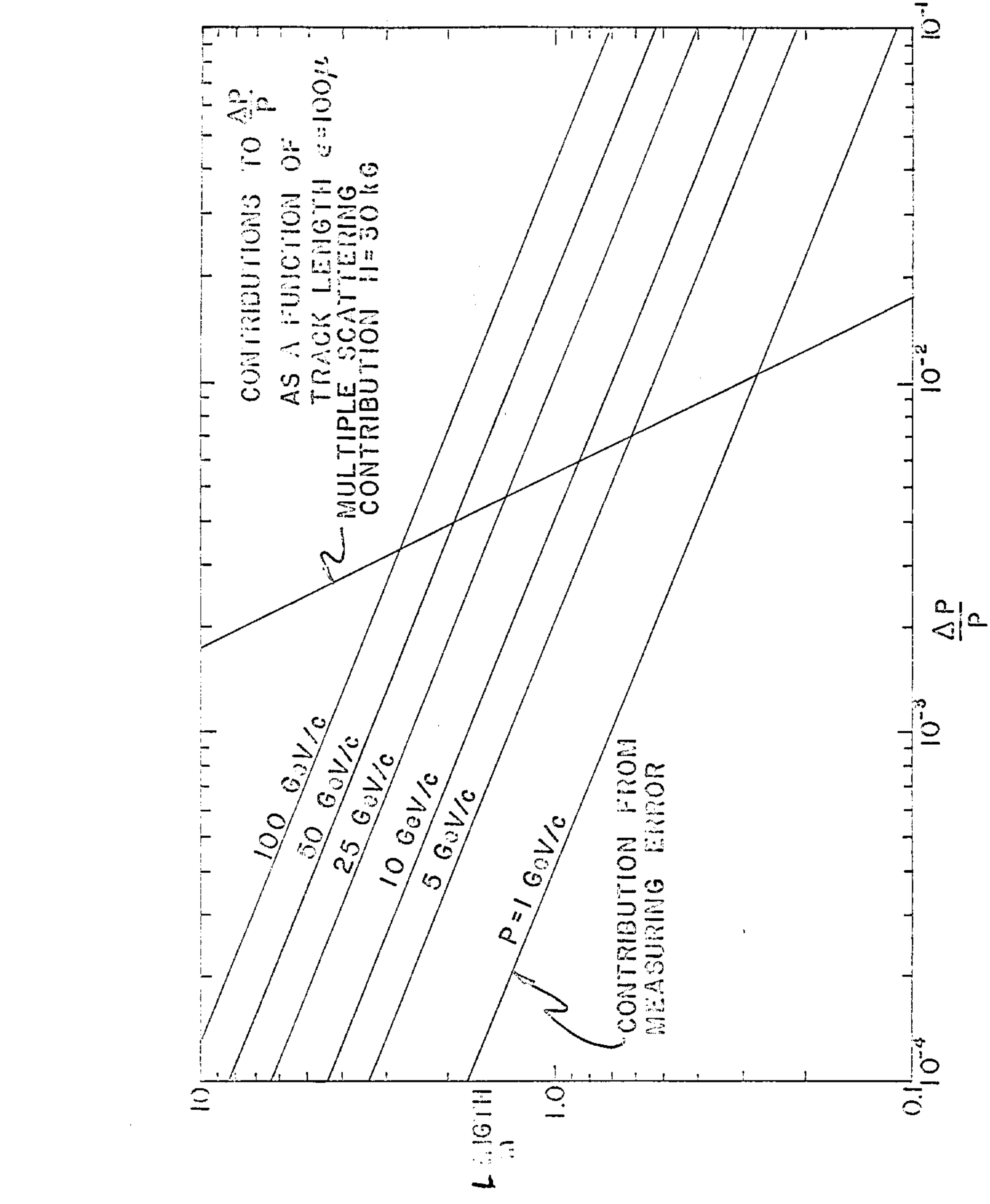
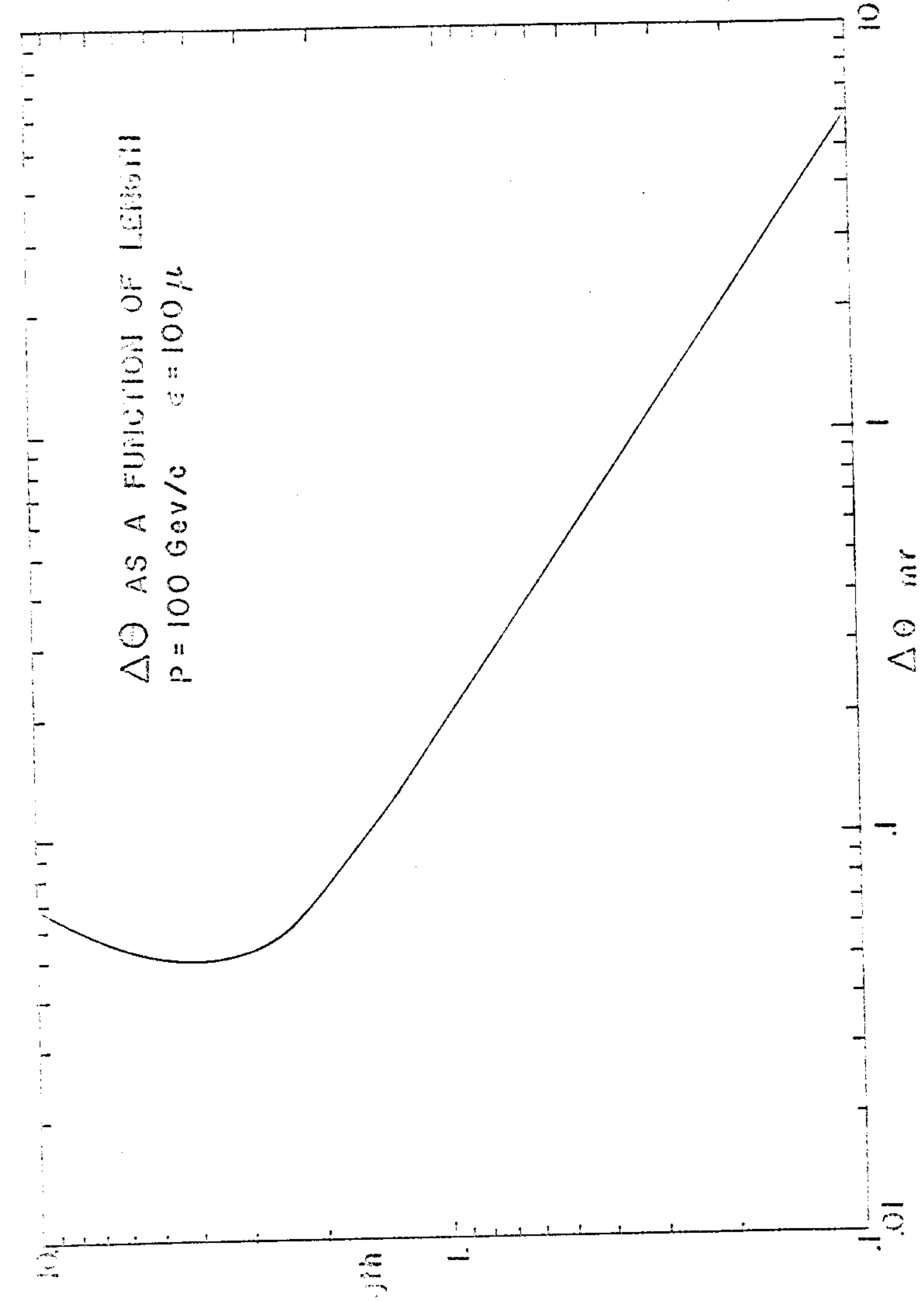

OPTIMUM TRACK LENGTH
VS
MOMENTUM FOR VARIOUS
SETTING ERRORS CHOSEN
TO MINIMIZE ANGLE
ERRORS
ε = 250 μ
ε = 150 μ
ε = 100 μ
ε = 75 μ
LENGTH
m
10.
1.
0.1
1.
10.
100
1000
MOMENTUM GeV/c

Figure 2


CONTRIBUTIONS TO $\frac{\Delta P}{P}$
AS A FUNCTION OF
TRACK LENGTH $\sigma=100\mu$
MULTIPLE SCATTERING
CONTRIBUTION H=30 kG
100 GeV/c
50 GeV/c
25 GeV/c
10 GeV/c
5 GeV/c
P=1 GeV/c
CONTRIBUTION FROM
MEASURING ERROR
$\frac{\Delta P}{P}$
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10
1.0
0.1


ΔΘ AS A FUNCTION OF LENGTH
P = 100 Gev/c ε = 100 μ
Δθ mr
10
1
.1
.01
Length m
10
1
.1